LIMITED CIRCULATION

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Odour frequency diagrams for livestock units in England and Wales - a preliminary analysis

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SUMMARY

Wind speed and direction data from a number of anemograph stations in England and Wales have been used with estimates of atmospheric stability to determine the frequency and magnitude of odours from an idealised livestock unit for different wind directions. Substantial differences between results from different stations were found, resulting from coastal and topographical influences and probably also more local features such as buildings near the anemographs. At relatively sheltered sites a simple analysis of wind frequency against wind direction was found sufficient to indicate not only the more likely directions of travel of the odours, but also that the strongest odours would travel most often in these same directions. In most cases the least offence is likely to be caused by positioning livestock units within the quadrant to the North East of sensitive areas.

1. Introduction

Useful estimates of the probable frequency and strength of odours at a place in the vicinity of an odiferous livestock unit may be obtained from wind speed and direction data used in conjunction with estimates of atmospheric stability derived from cloud amount and wind speed: an example for a village near a turkey unit in Norfolk has been given by Thompson and D'Costa (1983). The method may be generalised by including winds from all directions so that the odour problem can be assessed for places lying in any direction from the unit. The results from such analyses provide pertinent information for the siting of new units, especially when the wind frequency diagram for the local area lacks circular symmetry. The present memorandum outlines a simple method of deriving odour frequency diagrams, and applies this method with meteorological data from six stations to provide a broad picture of how such diagrams are likely to vary across England and Wales (a simpler analysis carried out for a further six stations is described in Section 4 of this paper).

2. Data

The positions of the stations are shown in Figure 1. Observations of wind speed, direction and cloud amount were used from each of the six main stations. The data period was 10 years (1972-1981): somewhat more representative results might perhaps be obtained using a 20-year period of data, but records at some stations in the years 1962-1971 were not continous - selection of alternative stations in these cases would have led to a less satisfactory geographical coverage of England and Wales.

3. Data analysis

The data were sorted into 10° wind sectors in five wind speed ranges, separately for day and night. Calms were assumed to be distributed equally between all wind directions, and were assigned to the lowest wind speed range. A further sub-division was used according to the amount of cloud. Each category was then assigned an atmospheric stability according to Pasquill (1961). The scheme is outlined in Table 1.

Table 1 Stability classification for wind frequency analysis

(a) Nighttime (all months)

Speed range (kts)	Assumed mid-range speed (m/s)	Pasquill Categories	
		$< 5/8$ low cloud	$\geq 5/8$ low cloud
1-3	1	G	F
4-6	2.5	F	E
7-9	4	E	D
10-12	5.5	D	D
$\geq$ 13	7.5	D	D

(b) Daytime

Range kts	Mean m/s	Pasquill stabilities											
		Jan		Feb		March		April		May		June	
1-3	1	C[1]	D[2]	B	D	B	C	B	C	A	B	A	B
4-6	2.5	C	D	C	D	B	C	B	C	B	C	A	C
7-9	4	D	D	C	D	C	D	B	D	B	C	B	C
10-12	5.5	D	D	D	D	D	D	C	D	C	D	C	D
$\geq$ 13	7.5	D	D	D	D	D	D	D	D	C	D	C	D
kts	m/s	July		Aug		Sept		Oct		Nov		Dec	
1-3	1	A	B	A	B	B	C	B	C	B	D	C	D
4-6	2.5	A	C	B	C	B	C	B	C	C	D	C	D
7-9	4	B	C	B	C	B	D	C	D	C	D	D	D
10-12	5.5	C	D	C	D	C	D	D	D	D	D	D	D
$\geq$ 13	7.5	C	D	C	D	D	D	D	D	D	D	D	D

1: $< 7/8$ Low cloud 2: $\geq 7/8$ low cloud

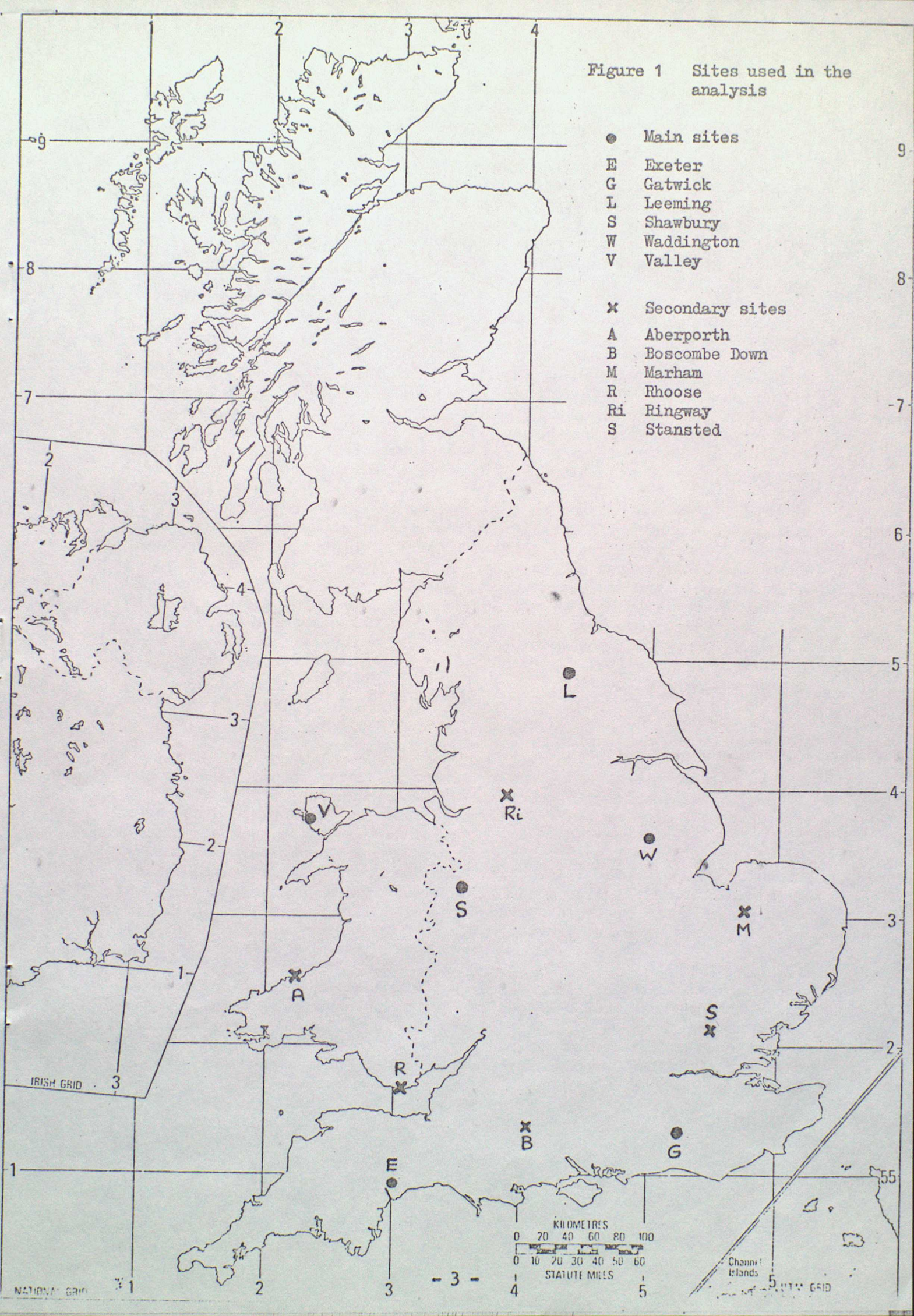
Figure 1 Sites used in the analysis
Main sites
E Exeter
G Gatwick
L Leeming
S Shawbury
W Waddington
V Valley
Secondary sites
A Aberporth
B Boscombe Down
M Marham
R Rhoose
Ri Ringway
S Stansted
IRISH GRID
NATIONAL GRID
KILOMETRES
0 20 40 60 80 100
0 10 20 30 40 50 60
STATUTE MILES
Channel Islands
UTM GRID

In order to calculate probable odour strengths it was necessary to select a standard configuration for the odour source, and a fixed distance of sampling. Ideas discussed by Thompson and D'Costa (1983) and Thompson (1983) were used here. The sampling distance was set at 500 m, and the source was idealized as uniform and circular, with diameter 50m. Local mixing over buildings producing the odour was assumed to distribute the odour uniformly over a height of 6m initially. Dilution of odour by vertical mixing was determined following Hosker (1974), but using the concept of a virtual source which is positioned further upwind by a distance depending on atmospheric stability in order to take account of initial mixing over the site. Dilution by lateral mixing was accounted for by integrating the various odour contributions from over the whole source area, assuming that each contribution produced an instantaneously sampled plume of odour.

The analysis proceeded by calculating for each combination of wind speed and atmospheric stability the concentration of odour on the axis of the composite plume from the odour source. The odour strengths were then classified into 7 classes C_o to $C_o/2$, ..., $C_o/2^n$ to $C_o/2^{n+1}$, ..., $C_o/32$ to $C_o/64$, and $> C_o/64$: here C_o was the highest calculated axial odour strength (Class G stability, with wind speed of 1 m/s).

The final step was to use the results from the wind frequency and direction analysis to calculate the relative frequency of atmospheric stabilities in each 10° wind sector: from this an indication of the relative frequency of different odour strengths was determined for each wind sector. A strict analysis would take into account the variation of odour plume meandering in different stability conditions, and the effect on odour frequencies for different directions from the odour source (Thompson and D'Costa, 1983). However, the simpler analysis described now is adequate to provide a broad picture of the regional variations in odour nuisance for different source-receptor directions.

4. Results and discussion

The main results are summarized in Figure 2. This gives for each month four plots of frequency of estimated odour concentration against wind direction for each of the six main stations: the four plotted curves show (i) the percentage frequency of occasions when odour concentrations lay within class 1 (lowest curve), (ii) frequency of occasions with odour concentrations in class 1 or class 2 (dashed curve), (iii) frequencies within classes 1, 2, 3 or 4 and (iv) frequencies when all values of concentration are included (highest curve) - here an isotropic wind field would give a percentage frequency for each 10 degree sector of 100/36 = 2.8.

There are some similarities between the frequency distributions from the different stations, but also substantial differences, and data from further stations are required to obtain a more coherent picture. A brief analysis was carried out therefore for six more sites to obtain monthly frequency diagrams for all odour concentrations combined (curves (iv) only) (See Figure 3).

The scale of the main weather systems which determine the general wind flow patterns over England and Wales ranges from hundred to thousands of kilometres. The passage of these systems past the British Isles is not random: for example the main depression tracks tend to lie to the North West of England and Wales. Thus, in the absence of coastal, topographical, local or diurnal effects one would find on average somewhat stronger winds further North and West (closer to typical depression centres), although the large scale of most weather systems would result in rather similar frequency distributions of wind direction over the whole area. However, inspection of Figures 2 and 3 shows that more local influences can also have a large effect on wind frequency distributions. It is important to distinguish here between the factors which alter the wind direction distribution, and those affecting wind speeds. The first set of factors changes the shape of the top curves in Figure 2 and the curves in Figure 3: the other factors are likely to alter the remaining curves in Figure 2. Each anemograph station will have its particular set of influences, and to attempt to isolate these and quantify their effects is unrealistic. It is probably more helpful to use the present data to illustrate the factors and their effects in broad terms, so that the representivity of wind data from any station when used to provide an analysis of the frequency of odours at a nearby livestock unit can be assessed.

The first of the factors which will be discussed is proximity to a coast. Stations near the coast will be windier than inland sites when the wind blows off the sea because the higher surface fraction of land compared with sea progressively reduces wind speed as distance from the coast increases. The distance from the coast at which the new equilibrium value of speed is reached is a function of surface roughness and atmospheric stability: a rough working figure for this distance is of the order of 10 km. This effect explains the important difference between the frequency curves for Valley, and those for sites further inland. In general the shape of the four frequency curves for each month for an inland site are similar, so that the upper curve gives not only the directions from which odours will be blown most often, but also provides a fairly good representation of the frequency with which the most offensive odours will travel in particular directions. (This last hypothesis is well-supported by the data for Gatwick, Exeter and Shawbury, but less so in the case of Leeming and especially Waddington: an explanation of this is provided by the wind speeds at the various stations (Table 2). Thus Waddington has the

Table 2 Median annual wind speeds

Station	Median Speed (kn)
Exeter	8.0
Gatwick	7.6
Leeming	8.8
Shawbury	7.9
Waddington	9.6
Valley	13.3

Aberporth	12.9
Boscombe Down	10.1
Marham	9.1
Rhoose	10.1
Ringway	8.9
Stansted	8.5

highest median speed of this group. In the South Westerly quadrant (where winds usually occur most frequently) the winds are often strong and then the effects of nocturnal cooling on density stratification near the surface, and hence atmospheric stability, will often not be large enough to reduce winds to the low values required for the strongest odours to occur: consequently a trough rather than a peak occurs in this wind sector in the bottom frequency curve (curve (i)). At the less windy sites the usual decrease of wind speed at night will more often be large enough to maintain the peak in the South Westerly sector for all odour concentrations). At Valley the most frequently observed winds also lie in the South Westerly quadrant in most months (uppermost curve in Figure 2) but the three lower curves generally show a trough rather than a peak in this sector. This is because the small land fetch for these wind directions is insufficient to reduce winds very often to values where high odour concentrations can be experienced. It is seen that there is a better correspondence between the four curves for winds between North East and South East, where the longer land fetch allows a greater reduction of speed.

A less obvious consequence of proximity to a coast may be deflection of the wind into preferred directions. A clear example of this is provided by the data from Rhoose (Figure 3). Here there are very pronounced peaks in the wind distribution in the Westerly and North Easterly directions every month, giving these distributions a substantially different shape from those at Aberporth and Valley. The observed predominance of winds at Rhoose is caused by the airflow tending to funnel along the Bristol Channel because of the lower surface friction of the sea.

Topographical effects are also important in their influence on wind fields at inland sites. Thus, although a comparison of the results in Figures 2 and 3 for all the inland sites shows many broad similarities, there are also detailed differences which are probably ascribable to topographical influences. Some of these effects may be very local (for example partial shielding of anemometer and wind vane for particular directions by "topography" in the form of buildings) while others may be produced by altitude variations in local terrain. Thus Leeming shows a pronounced peak in winds from a South South Easterly direction, and another for Westerlies, but a trough in the South Westerly direction. Ringway and Exeter on the other hand have major peaks for Southerlies and West North Westerlies, whereas Waddington has a South Westerly peak, as do Marham, Stansted and Gatwick.

The detailed differences in the frequency diagrams for the various stations used in this analysis make it difficult to draw up universal guidelines to assist for example in the siting of a new livestock unit to minimise odour nuisance to existing habitation. However, data from nearly every inland station used in this study indicate that siting in the quadrant to the North East of the dwellings would give less offence over the whole year. Also, for very windy areas well exposed to South Westerly winds, the unit

could be placed with advantage to the South West of human habitation, although only coastal and upland sites are likely to be useable reliably in this way.

If siting of the unit to the North East of dwellings is impossible the analysis has shown, for sites which are not exposed, that a simple plot of wind frequency against wind direction will suffice to identify those sectors where the most offensive odours will occur less often. In these cases it will be necessary to inspect records from several of the nearest anemograph stations, and carry out a site inspection to assess any special topographical influences, in order to confirm whether the analysed records will provide a reliable basis for decisions on siting.

5. Conclusions

The analysis has indicated the importance of local shelter, and topographical and coastal effects, in the wind frequency distributions which are derived from anemograph records. For these reasons a straightforward application of a wind frequency/atmospheric stability analysis to determine the siting of livestock units to give the least offence may not provide the best advice, especially when site and anemograph stations are far apart: records from several stations will usually have to be employed, and a site inspection made, before the best advice can be given.

For sites which are not exposed it has been found that the wind directions occurring most frequently are also those for which high odour concentrations are experienced most often. In these cases the simplest analysis of wind frequency against wind direction (using representative anemograph data) will be sufficient to provide the necessary advice on siting. In most cases positioning the livestock unit within the quadrant to the North East of the sensitive area would reliably reduce the risk of odour offence to inhabitants of that area.

Any comments or suggestions on this paper should be referred to the author.

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December 1983

References

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Thompson, N. 1983 Estimating the rise of "buffer zones" for pig farm odours, and comparisons with an Australian Code of Practice. Agricultural Memorandum No 973.

Thompson, N. and D'Costa, R. 1983 Estimating the frequency of offensive odours in the vicinity of livestock enterprises: a case-study for Norfolk. Agricultural Memorandum No. 981.

Figure 2

The diagrams show the expected frequency of occurrence of odour concentrations within 10 degree wind sectors.

The upper curve for each month includes all values of concentration: an isotropic wind field would in this case give a percentage frequency for each wind sector of 100/36 = 2.8.

The lower curve shows percentage frequency of occasions when odour concentration lay within class 1 (C_o to $C_o/2$).

The dashed curve shows frequencies for occasions with odour concentration above the lower limit of class 2 ($C_o/4$).

The remaining curve gives frequencies of occasions with odour concentration above the class 4 lower limit ($C_o/16$).

Wind directions are those from which the wind is blowing.

Figure 3

As Figure 2, except that only the upper curve (all values of odour concentration) is plotted.

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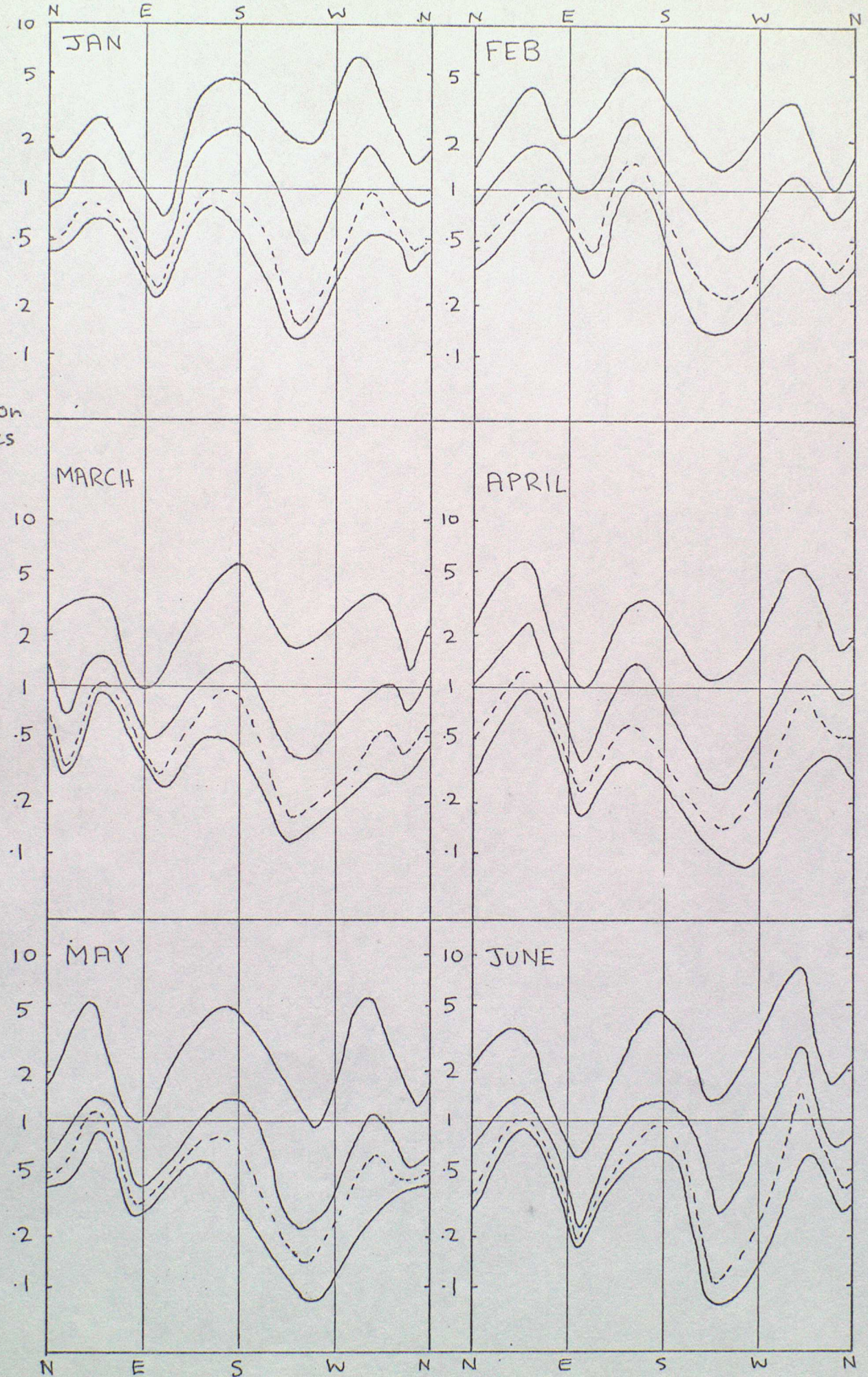
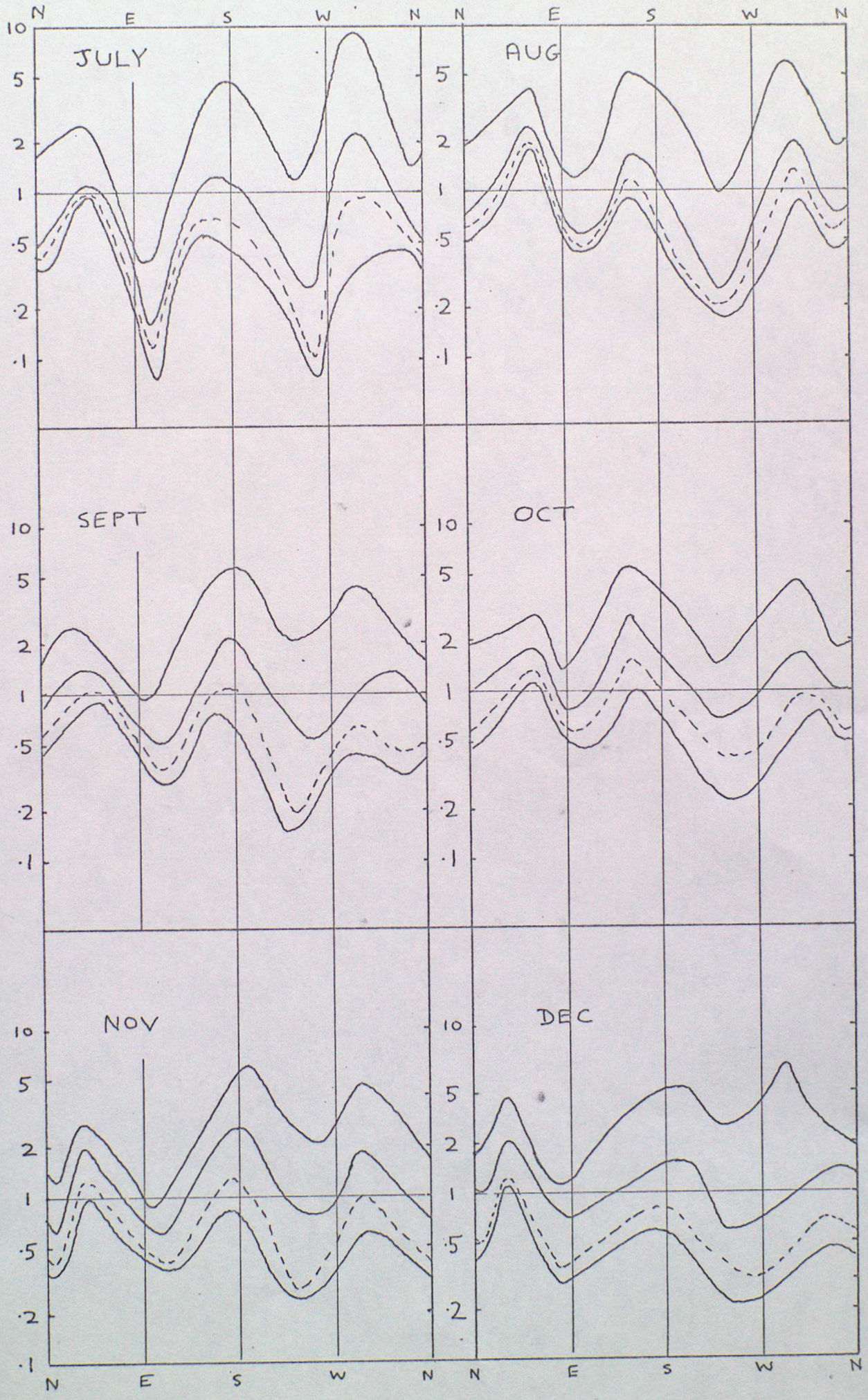


FIGURE 2

Odour concentration frequencies (expressed as percentage within each 10° wind sector)

EXETER



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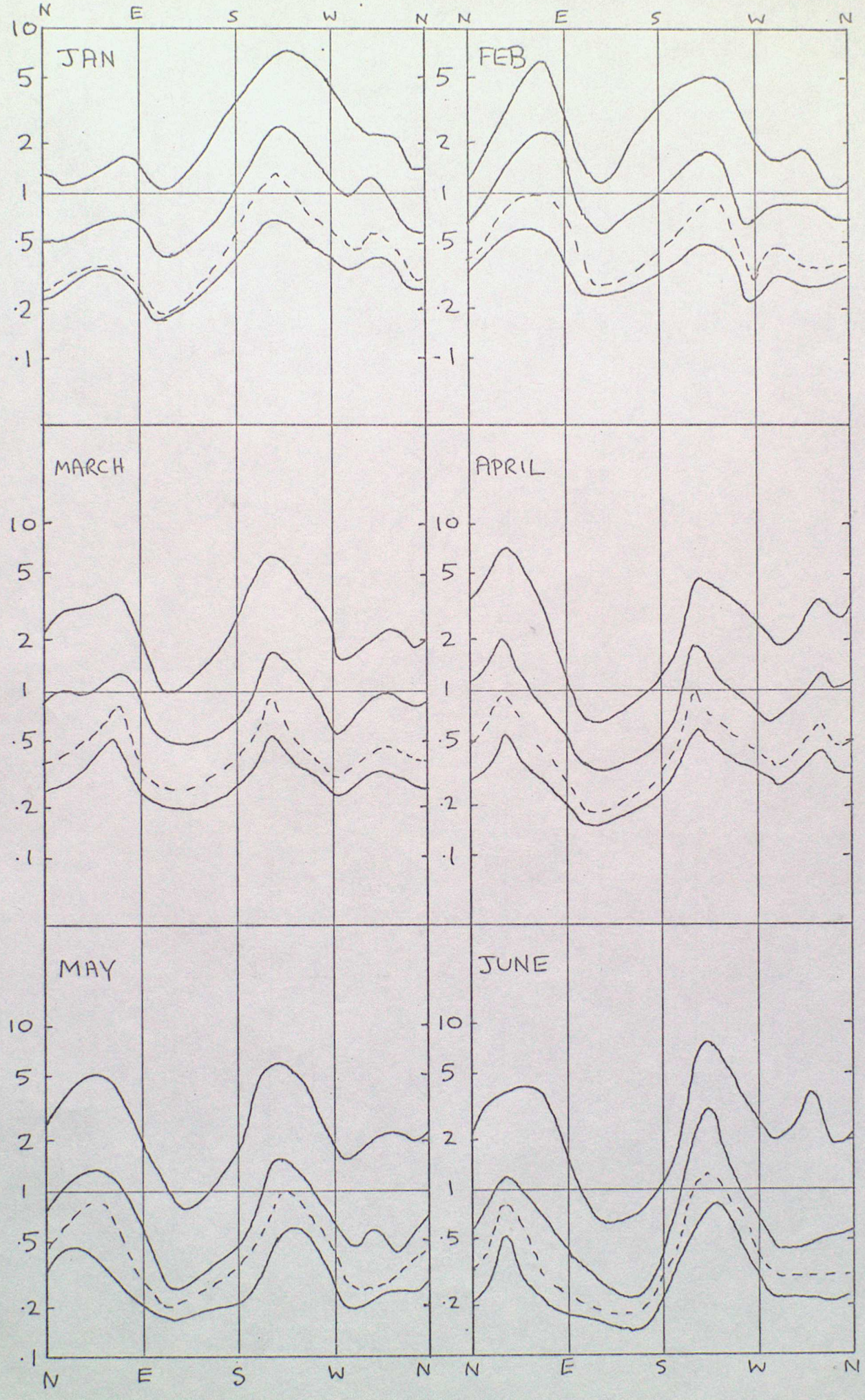

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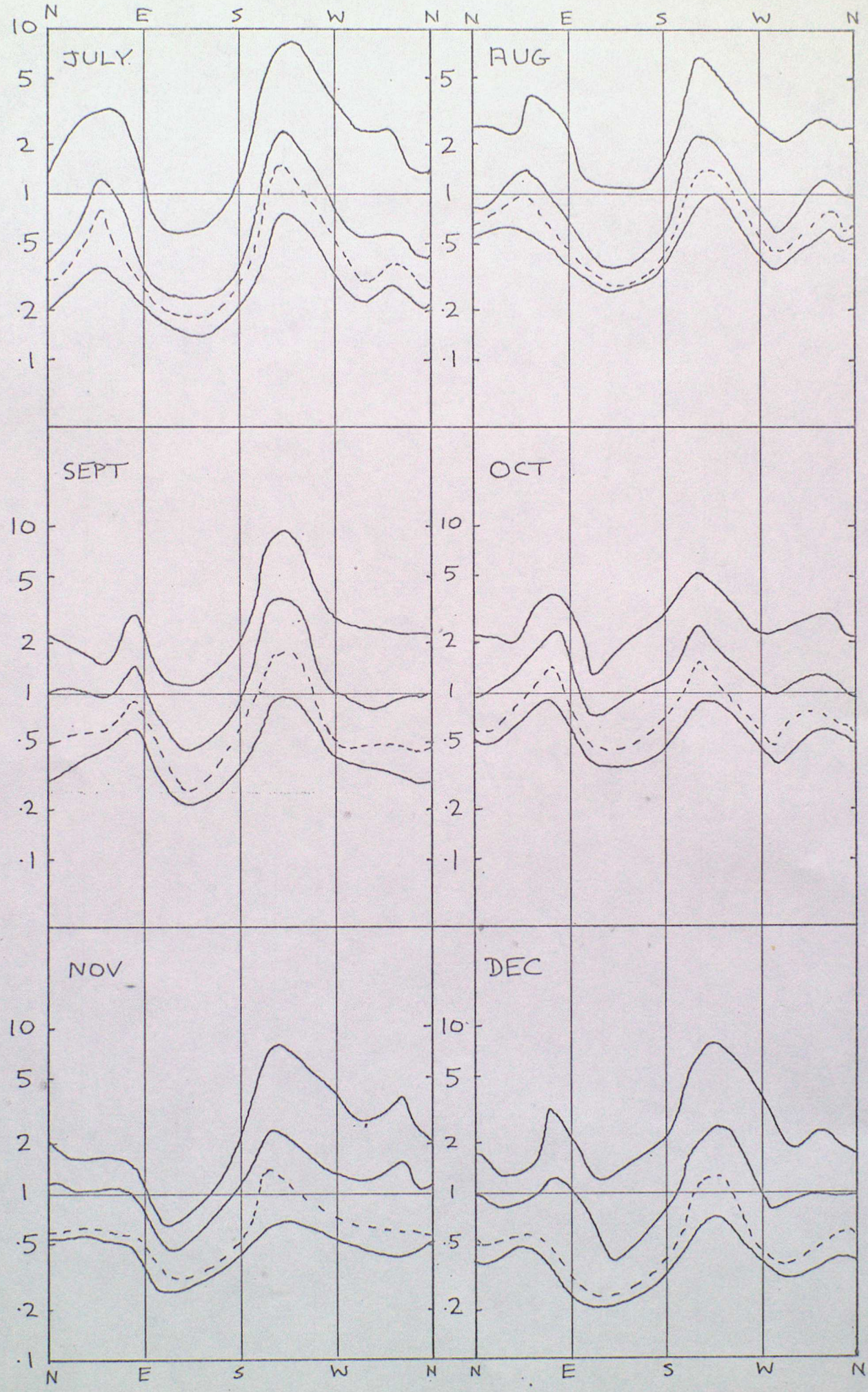

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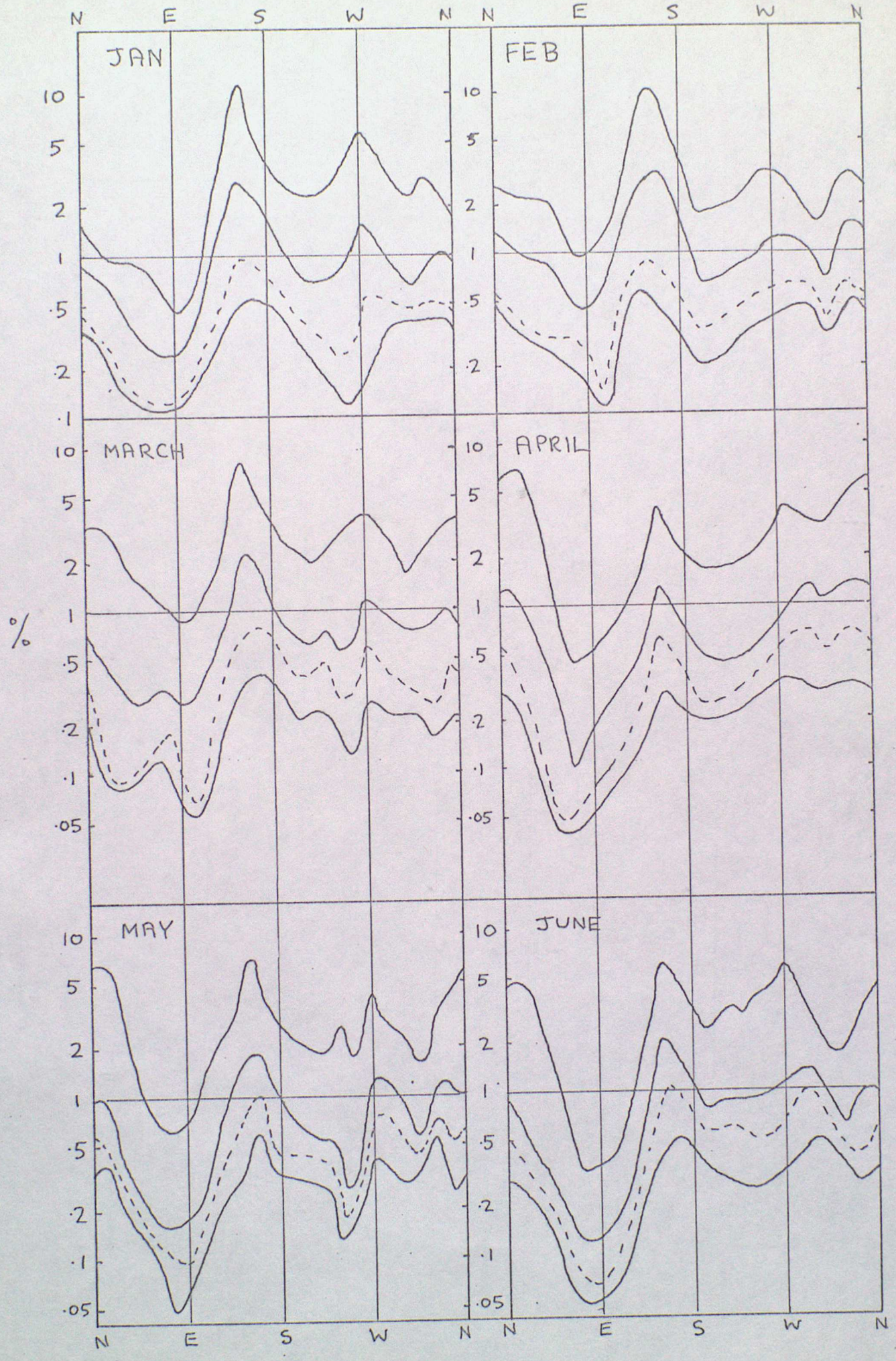

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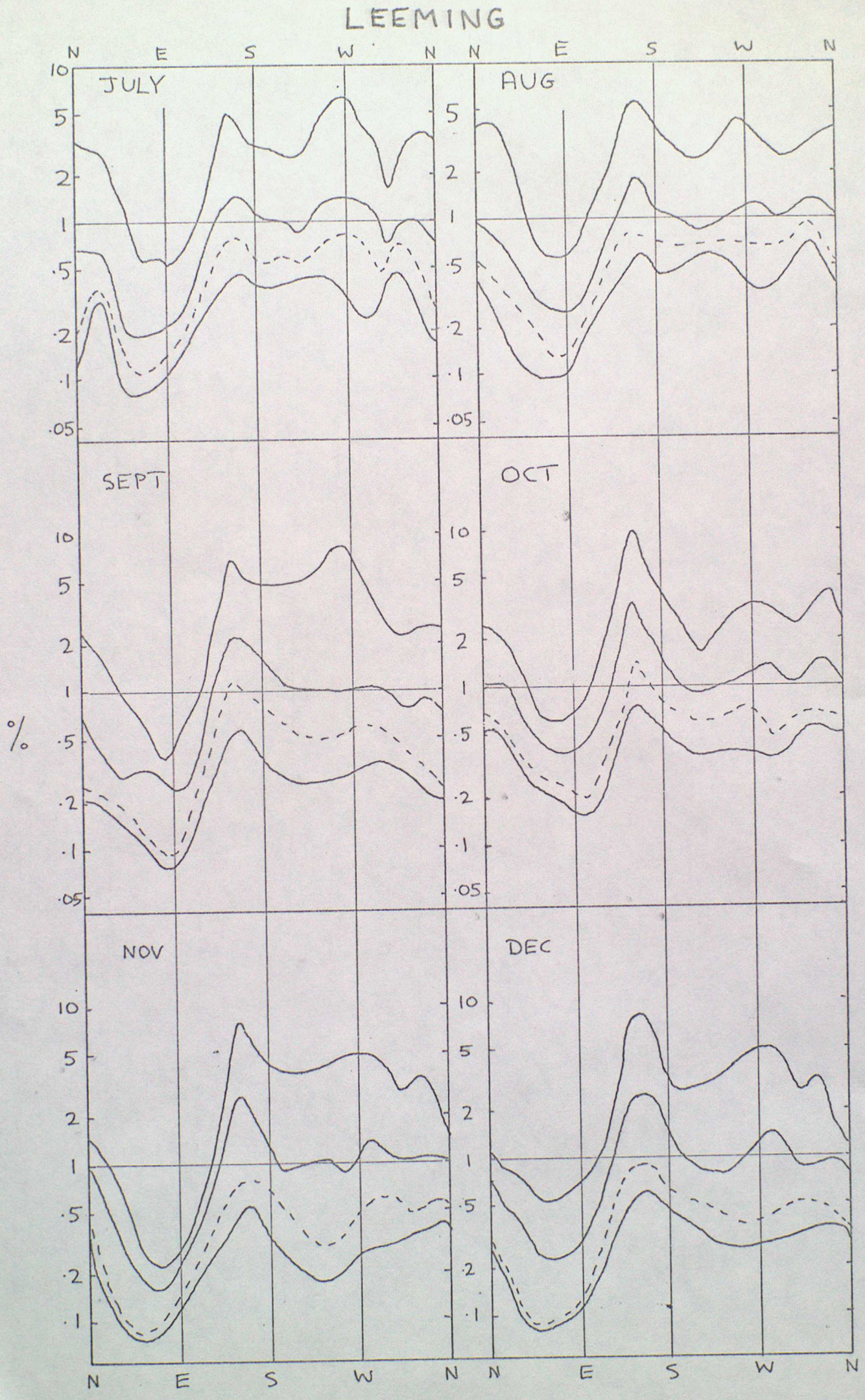

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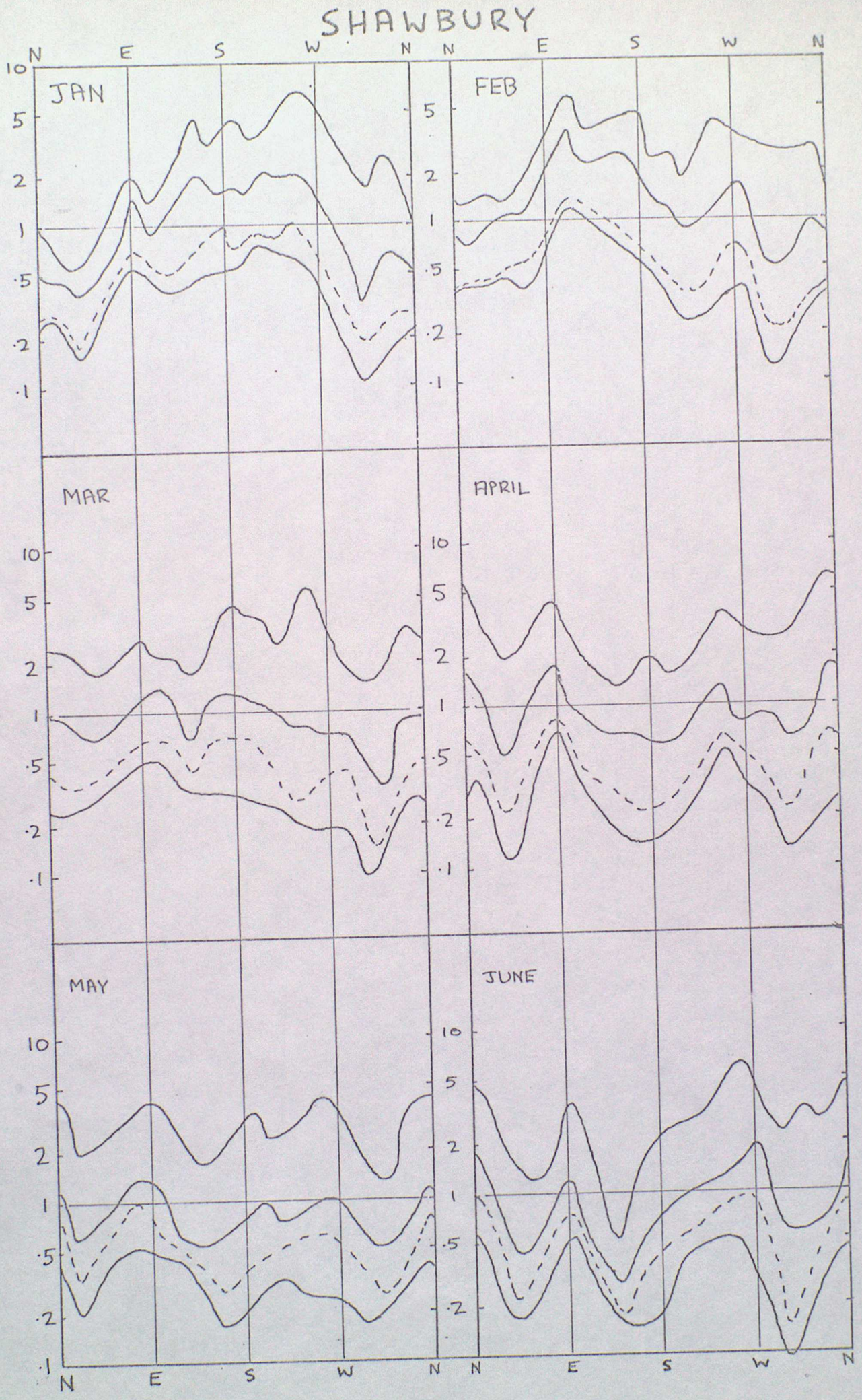

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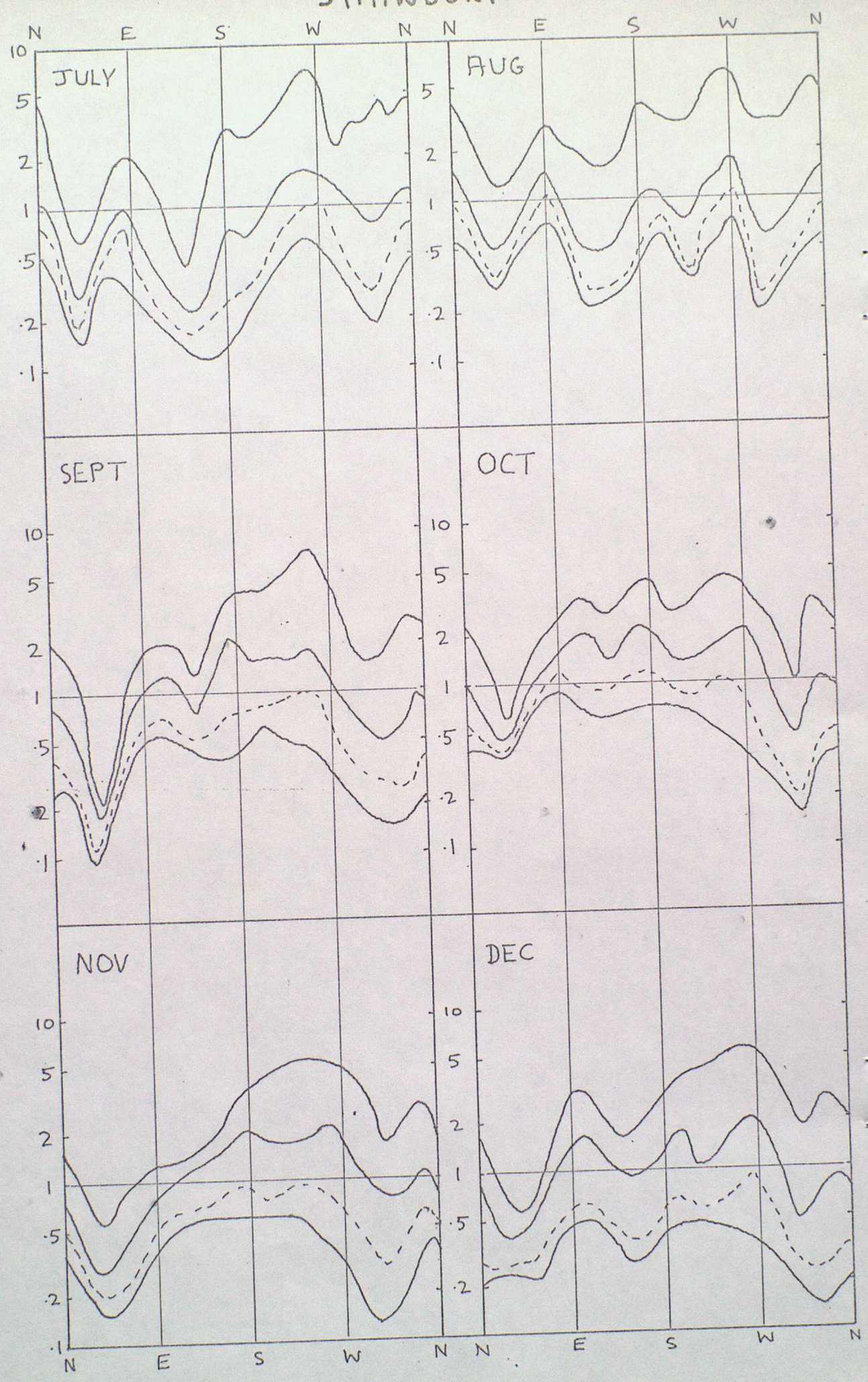

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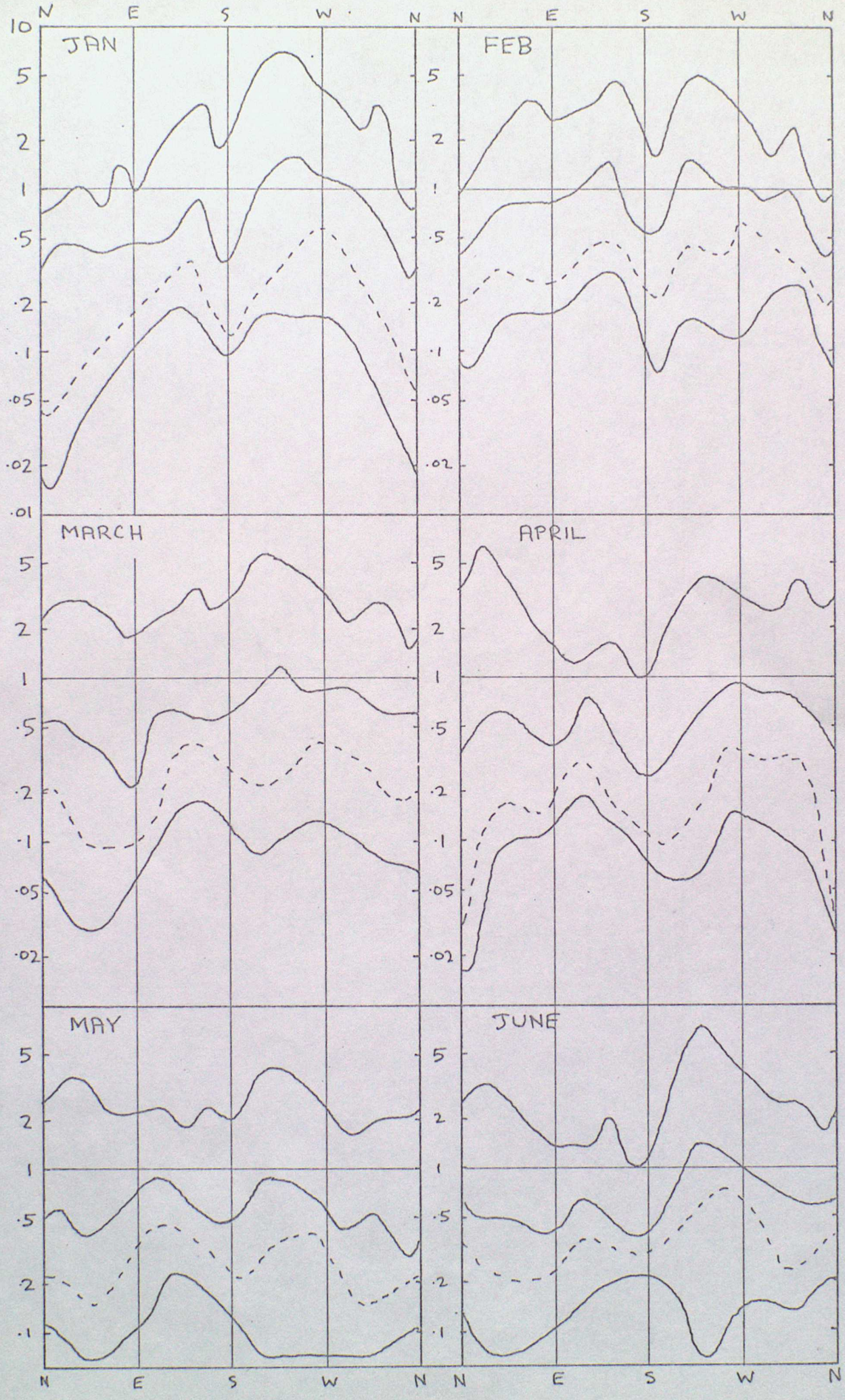
WADDINGTON



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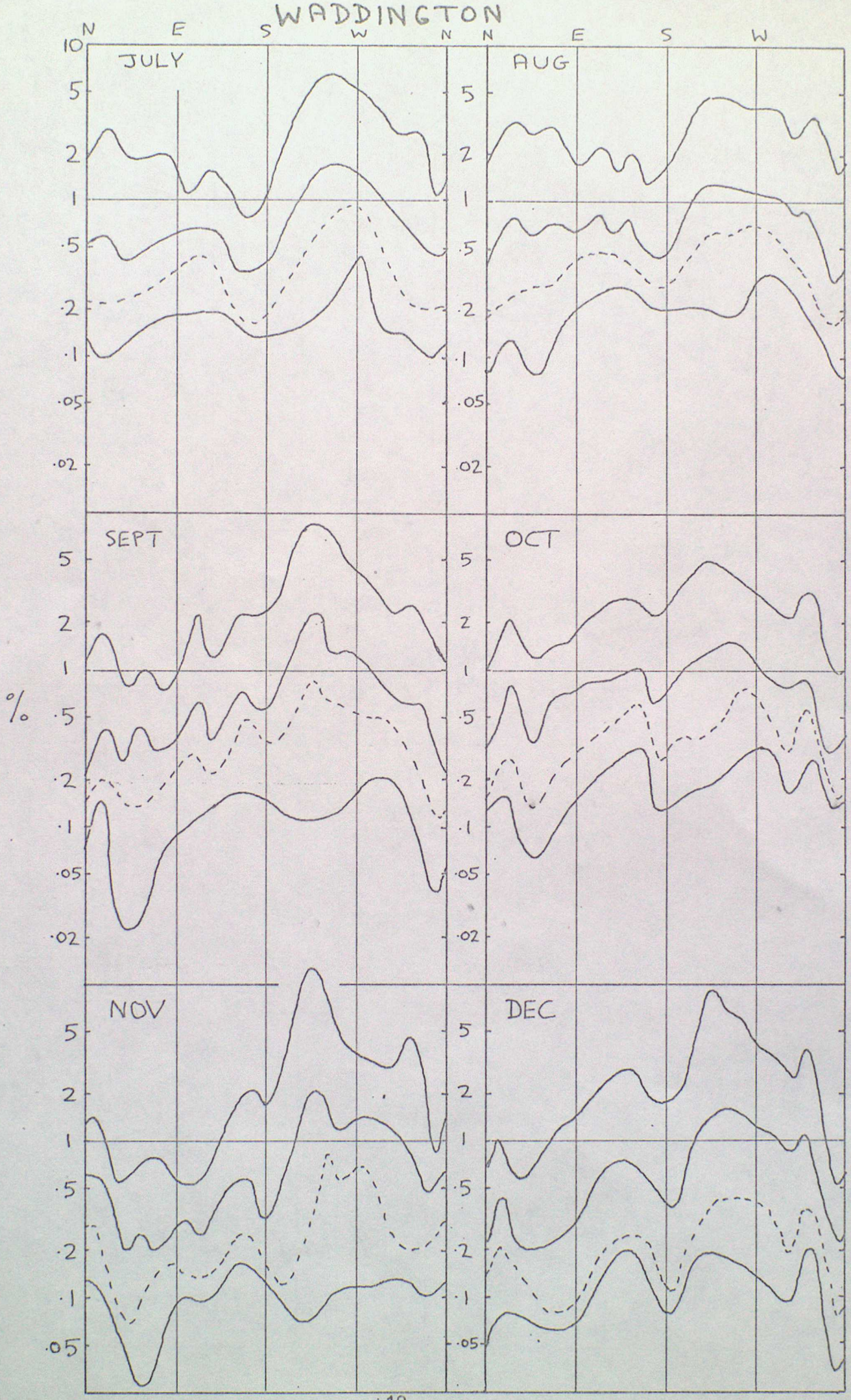

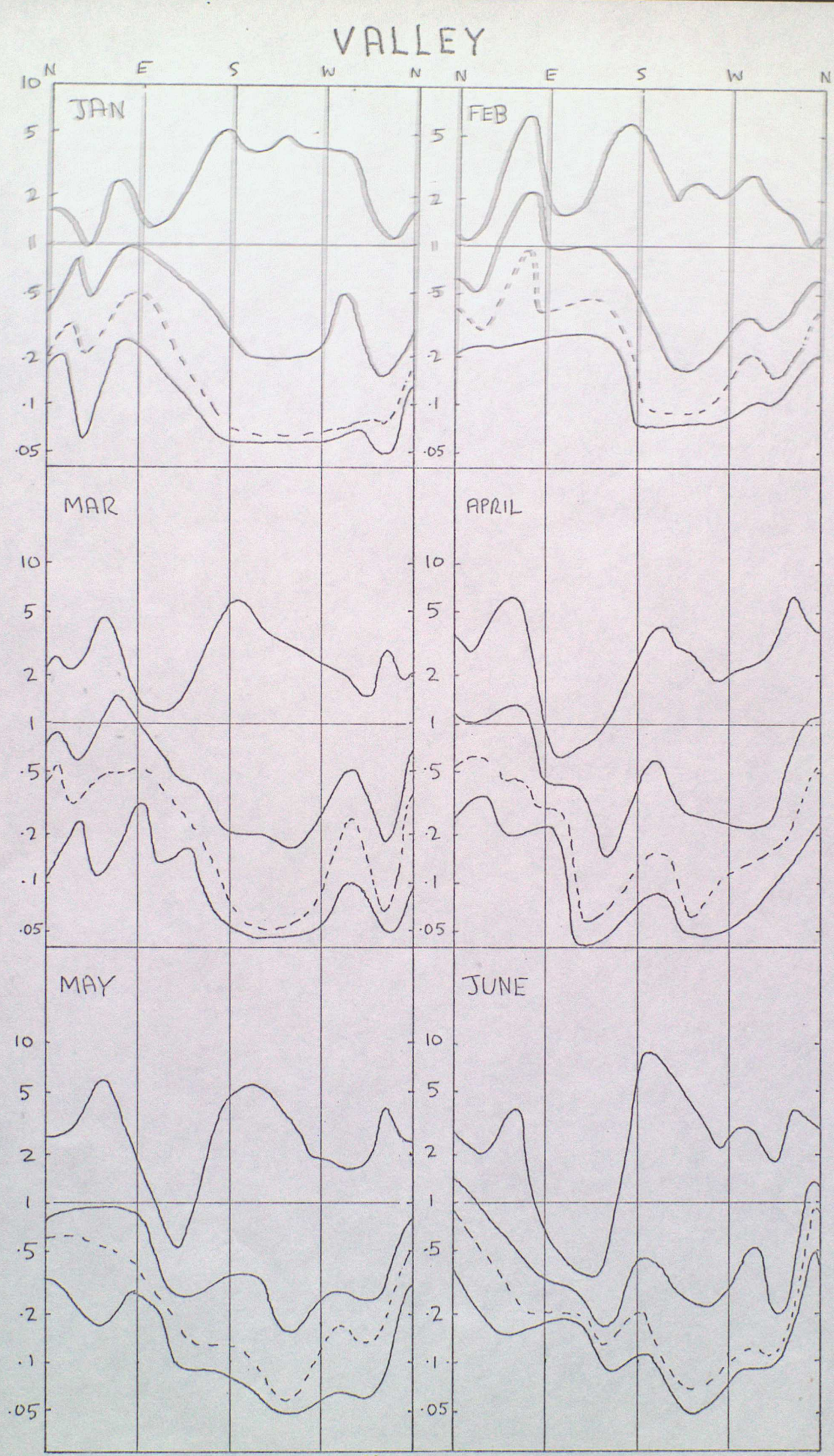

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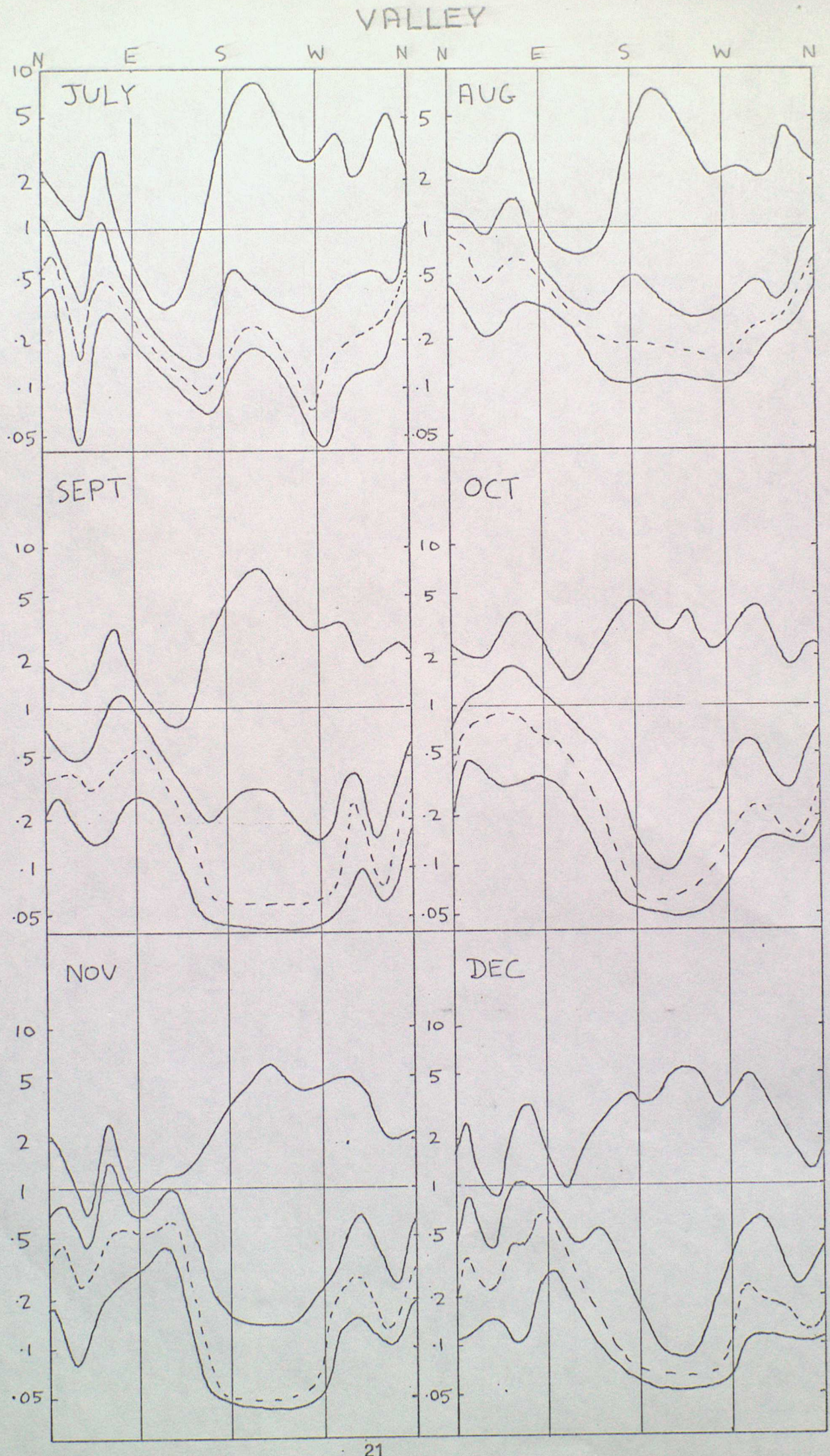

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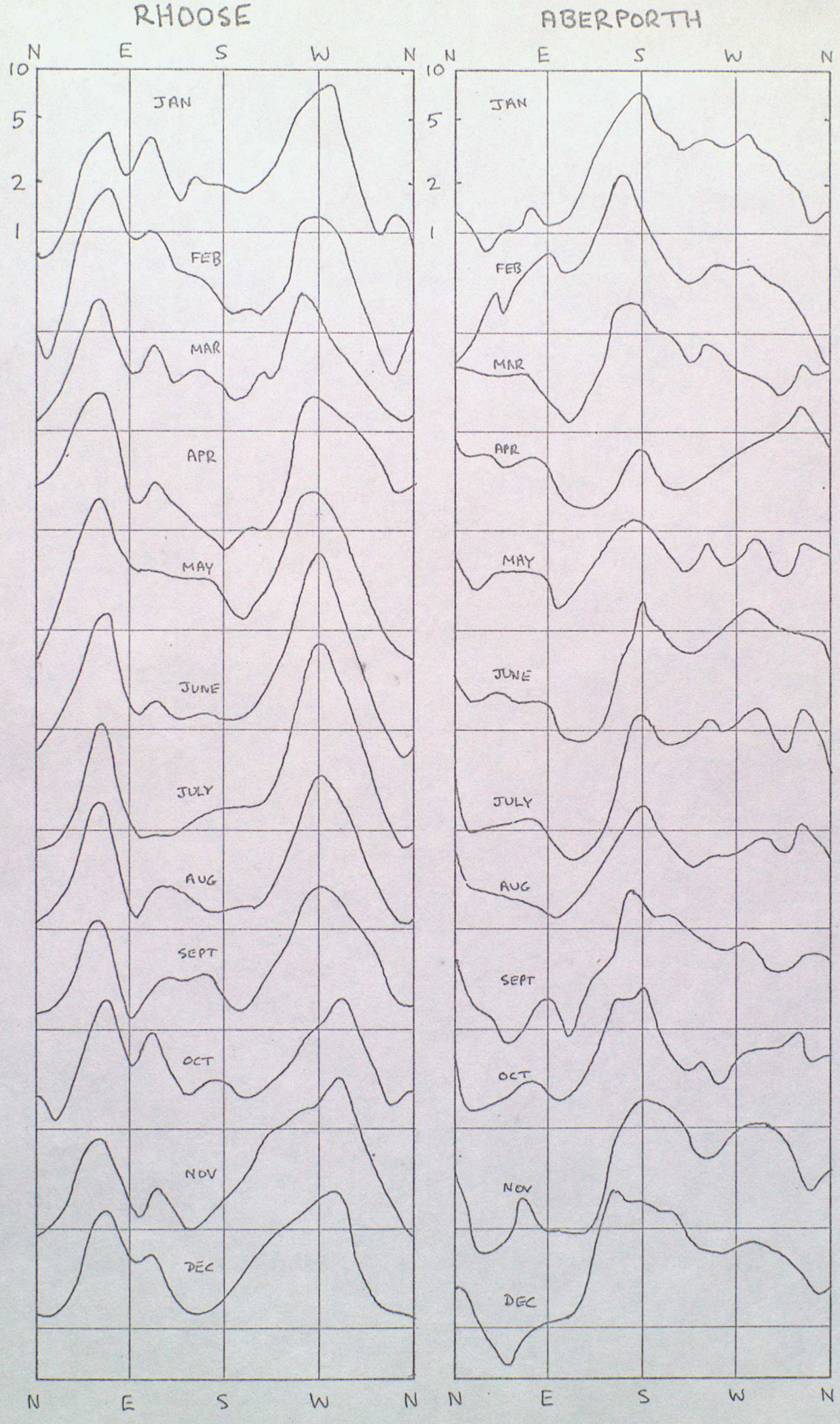
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Figure 3

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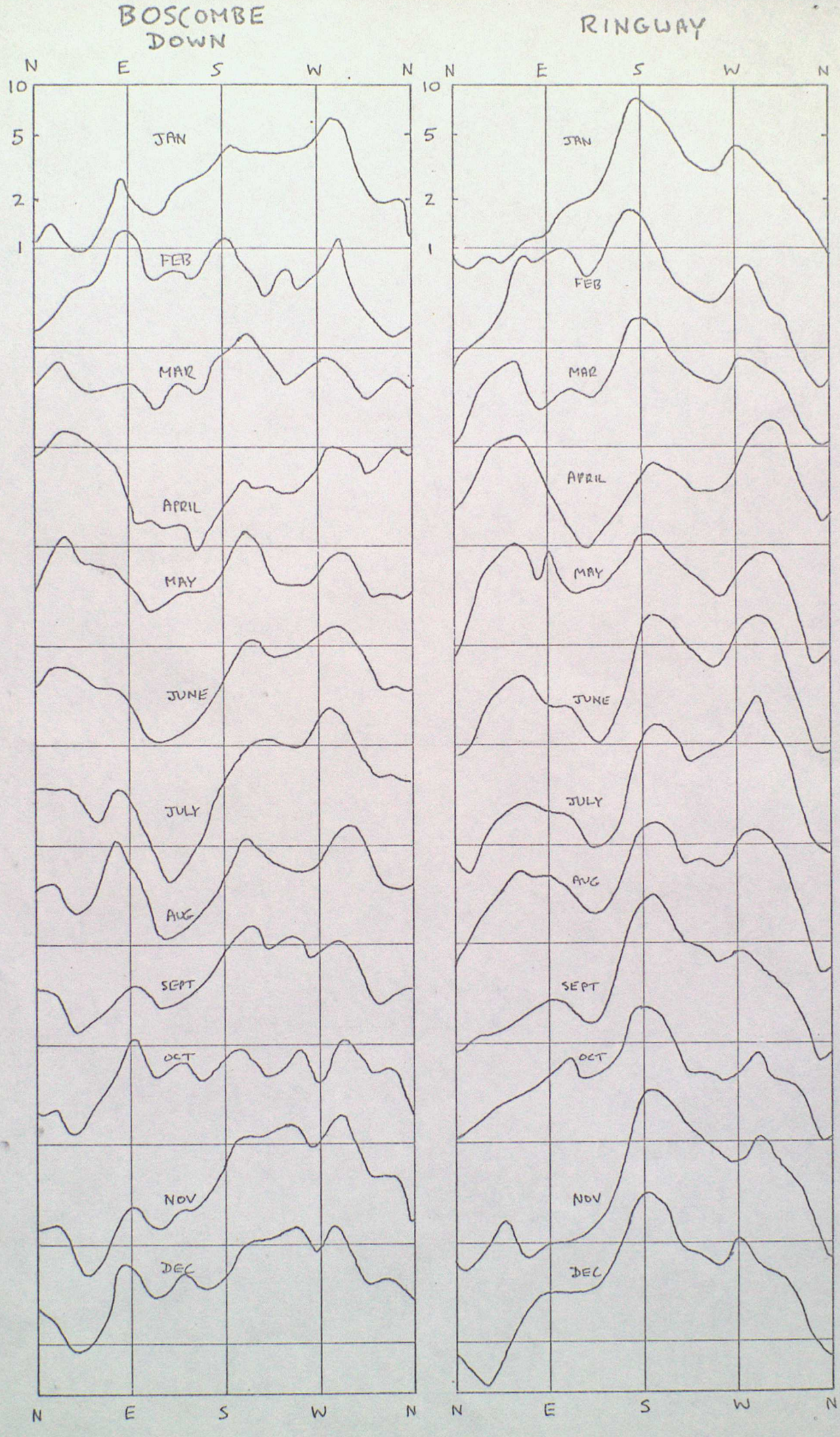
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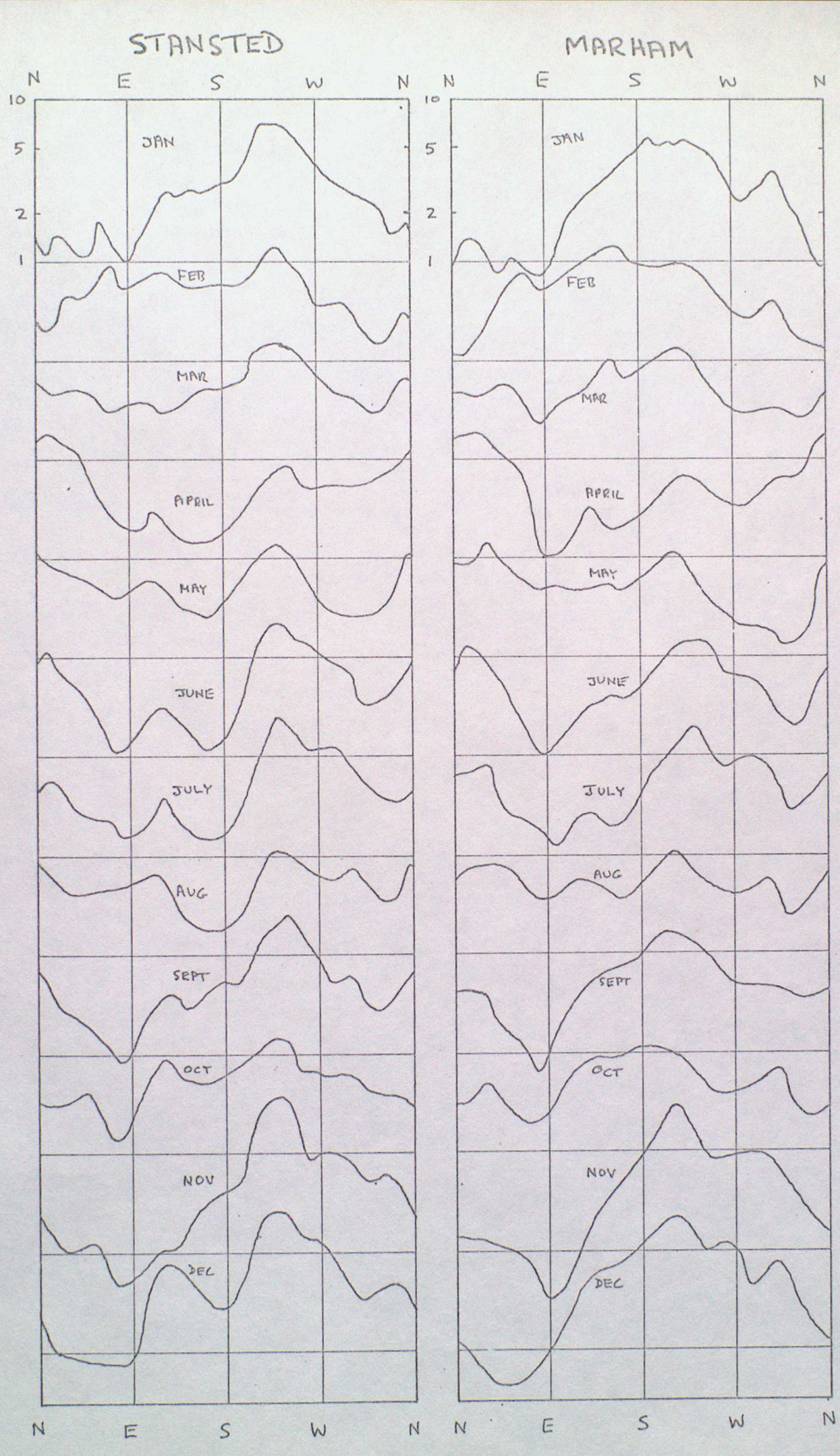
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